



Hardware Demonstration of the Feasibility and Value of Distributed Resources as a Solution to the Sensitive Load Problem

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Hardware Demonstration of the Feasibility and Value of Distributed Resources as a Solution to the Sensitive Load Problem

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Sensitive Loads



“The impact of momentary interruptions of power is extremely costly in terms of lost productivity and potentially damaged equipment at Oracle....Whether the electricity was free or cost three times as much would have absolutely no effect on the cost of our product.”

— Mike Wallach

“What is self-sufficiency worth to us [Oracle]? Millions of dollars per hour.”

— Jeff Byron

“Sun Microsystems has estimated that a blackout costs up to \$1 million per minute”

- Larry Owens, Silicon Valley Power

Different Power Quality Perspectives



UTILITIES PERSPECTIVE

For a typical distribution customer, there are less than four interruptions per year with a cumulative interrupted average of less than 2-hours/year

80 percent of the interruptions are due to distribution system components

CUSTOMER'S PERSPECTIVE

95 percent of electricity problems disrupting equipment and production are originated by voltage sags, and interruptions with duration less than 1/2 second

30-percent of production equipment contains electronics sensitive to power quality problems



Project Objective...



Demonstrate that small inverter based sources
can meet the demands of sensitive loads



Strategies...



- Use the inverter based source to remove voltage sags by injecting negative sequence currents
- Island sensitive loads with inverter based sources during power quality events



Objectives and outcomes



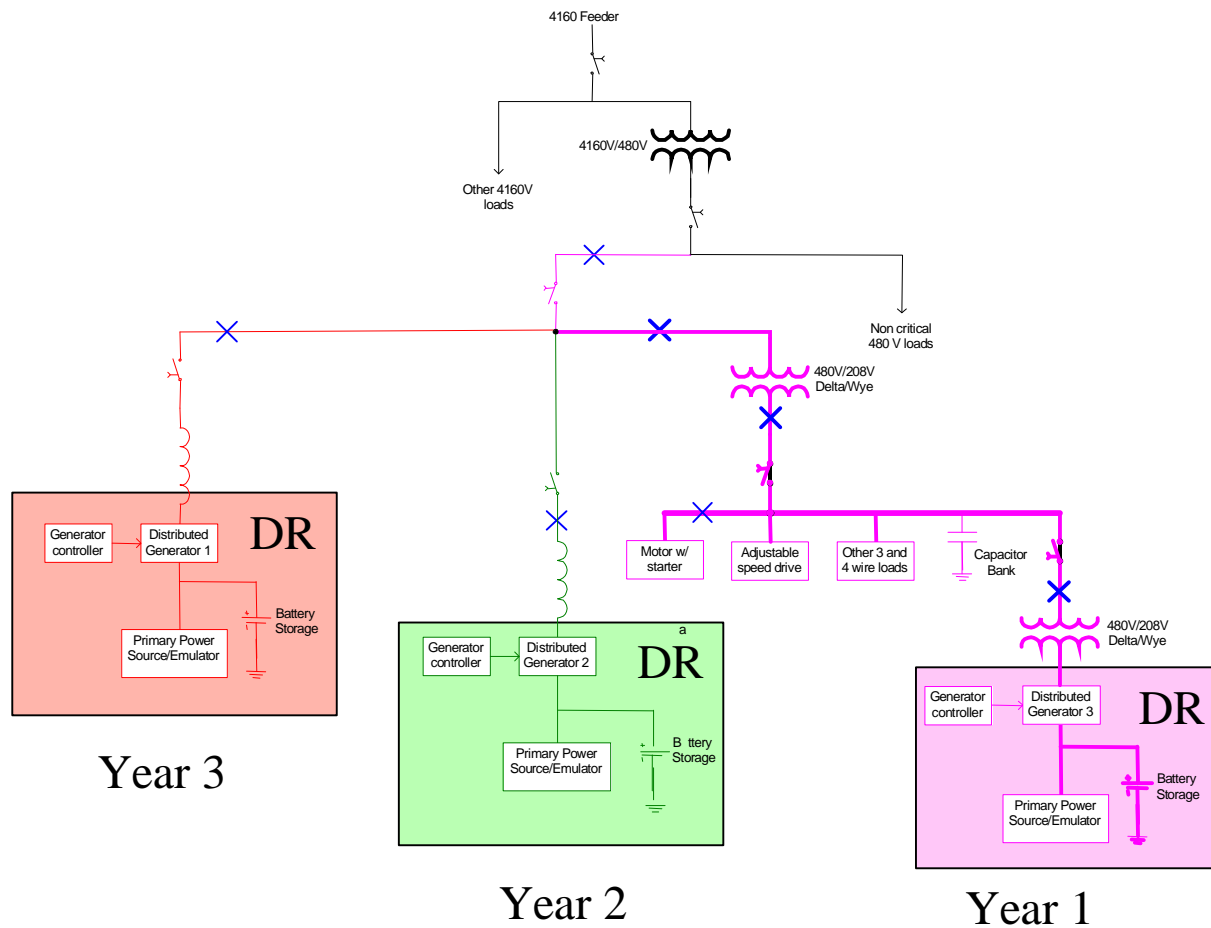
Year 1: Operation of a single inverter in island mode

- Simulation of control strategies
- Construction of prime mover emulator
- Investigated the operation of an inverter based source on our hardware platform

Year 2: Operation of two inverters in island and grid connect mode

Year 3: Expand to three inverters

Hardware platform

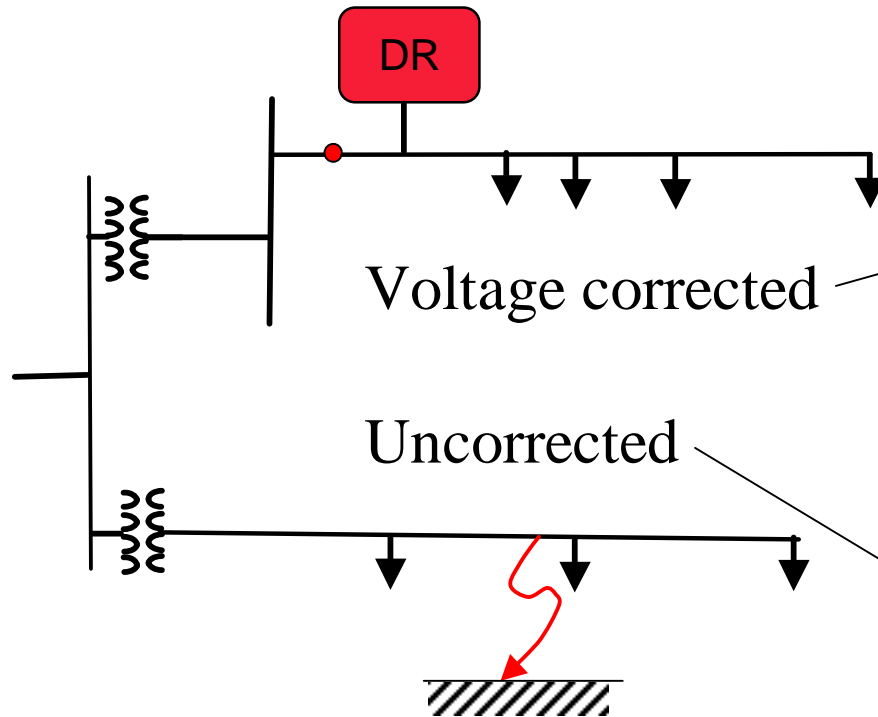


Hardware platform



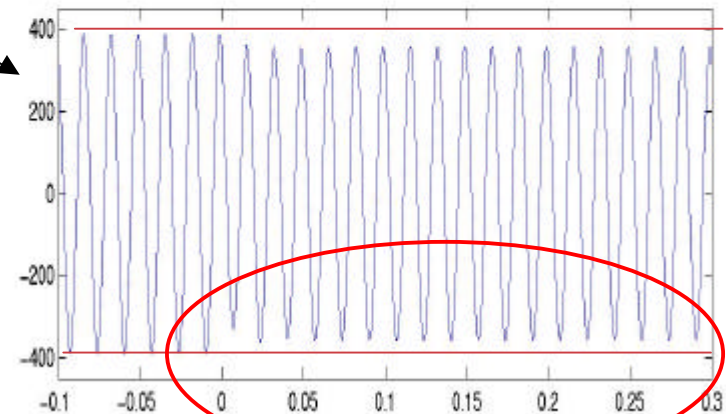
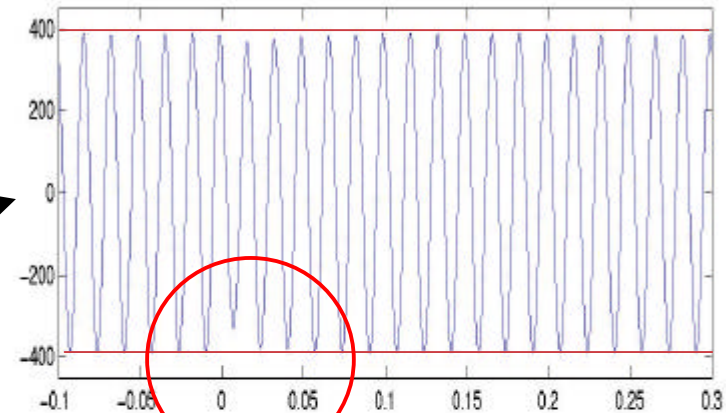
- Cable tray system for interconnections installed
- Physical plant wiring modifications completed
- Completed loading system
- Load center with measurement interface completed

Simulated sag correction



Voltage corrected

Uncorrected



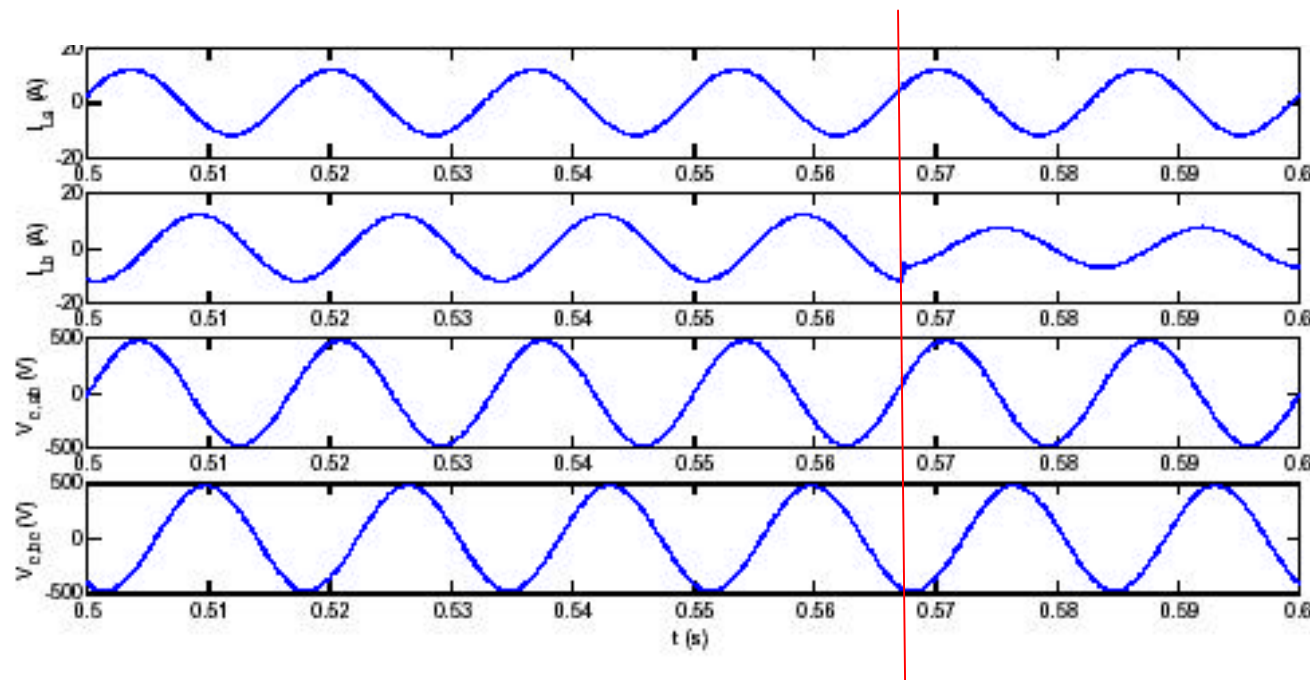
Sag correction

Balanced L-to-L voltages

Sensitive load

DR

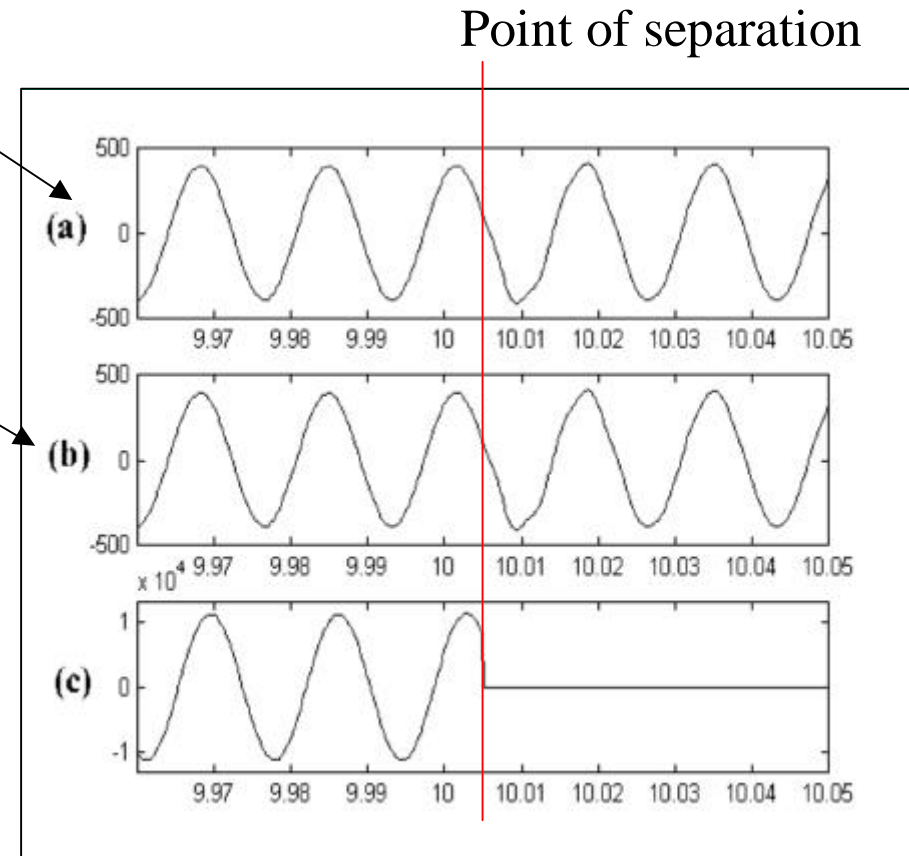
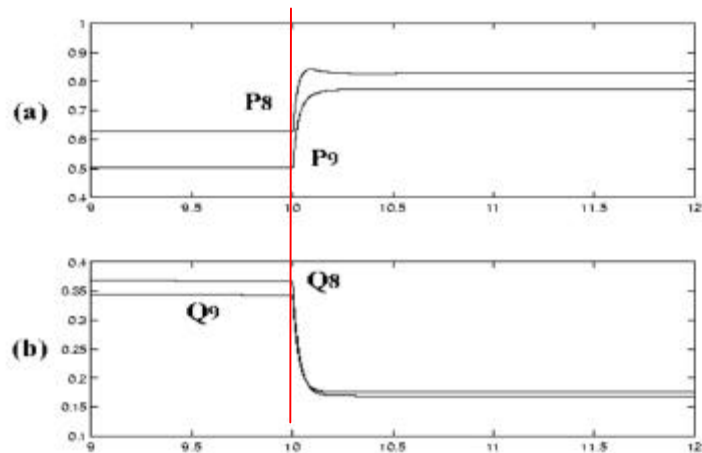
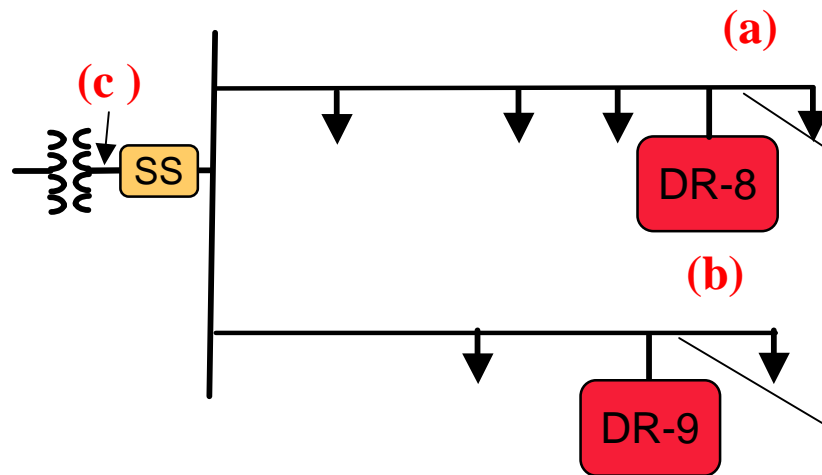
Unbalanced load



Unbalanced
Load currents

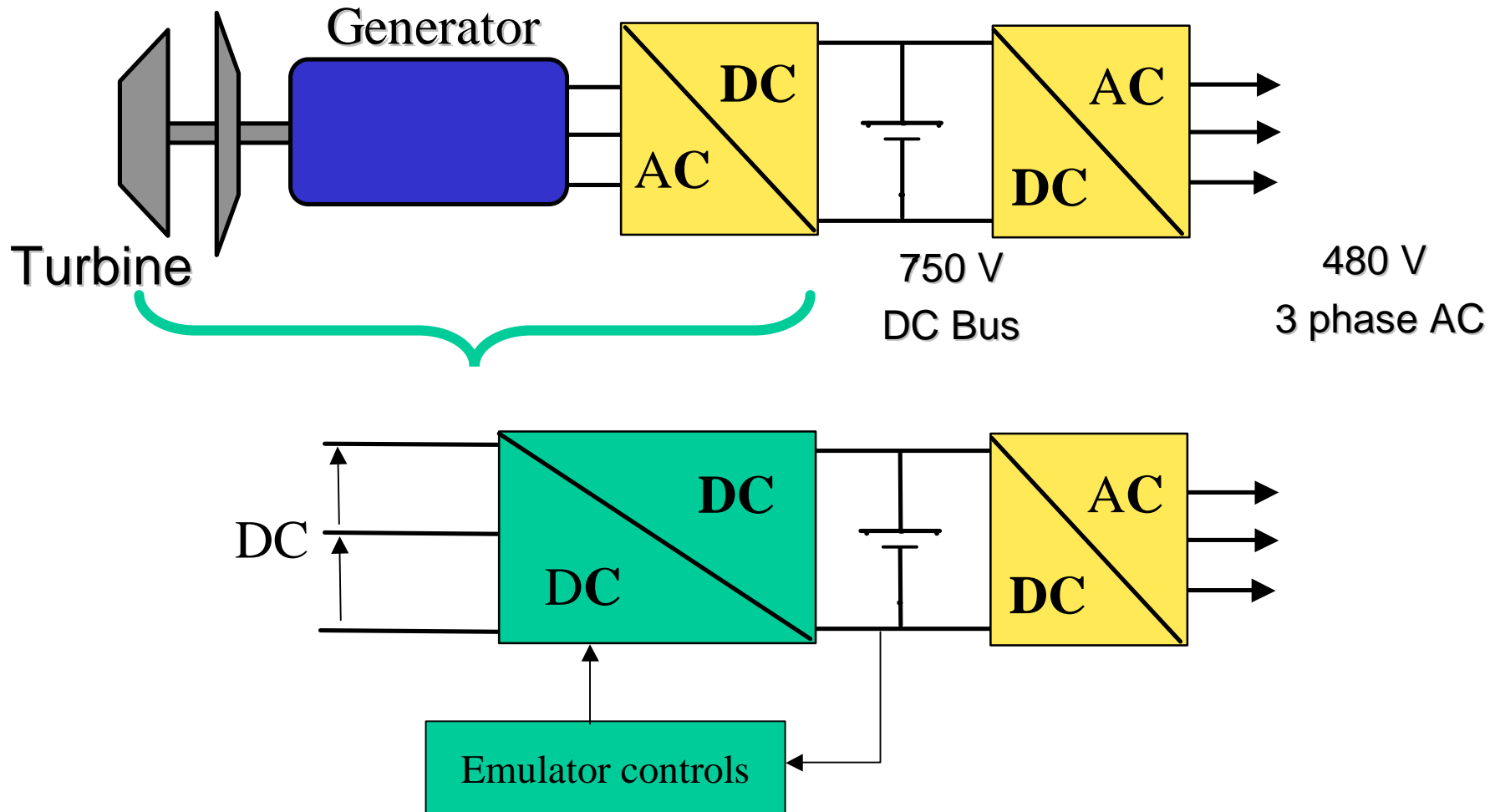
L-to-L Voltages

Islanding for sensitive load

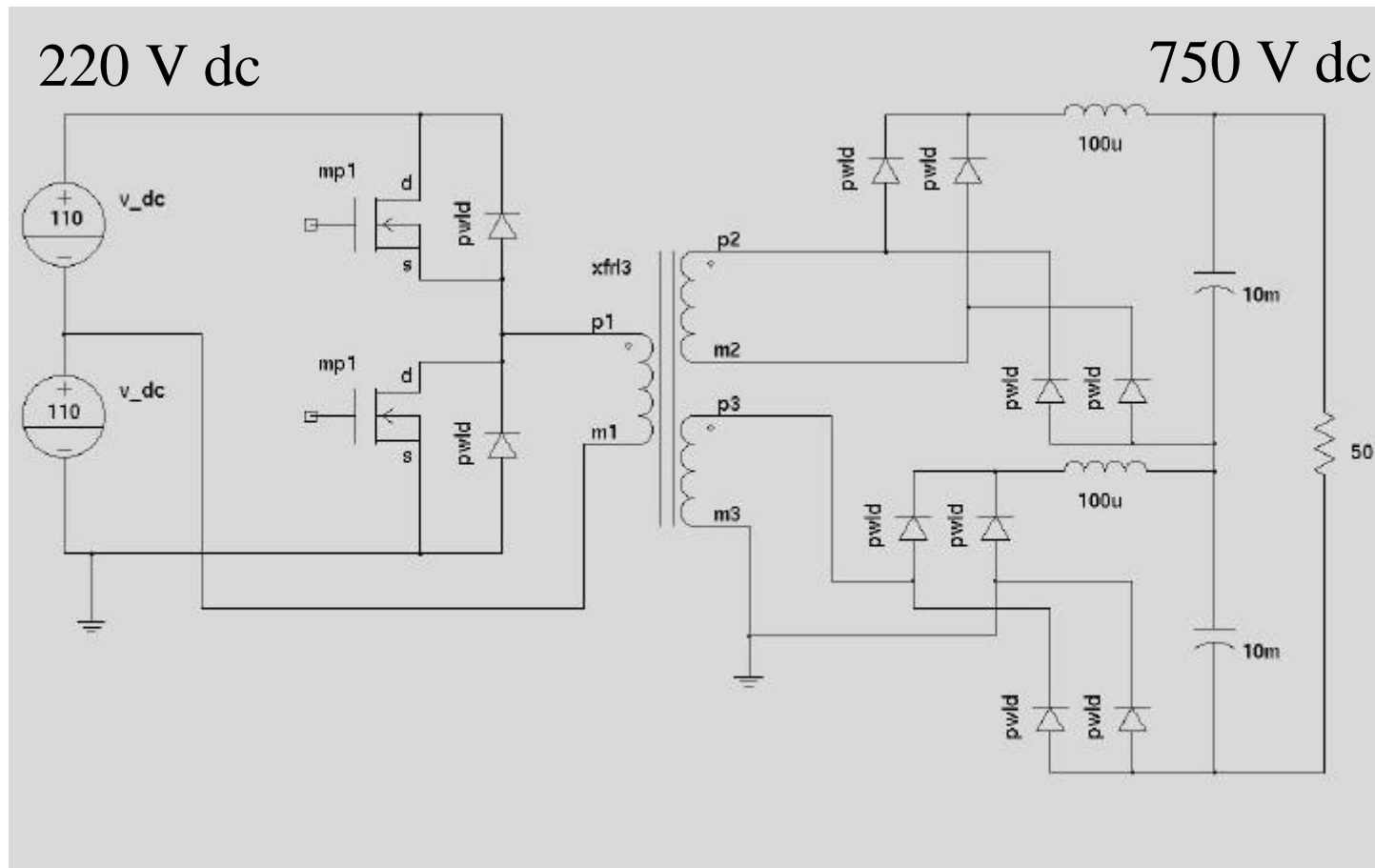


L-to-L voltages

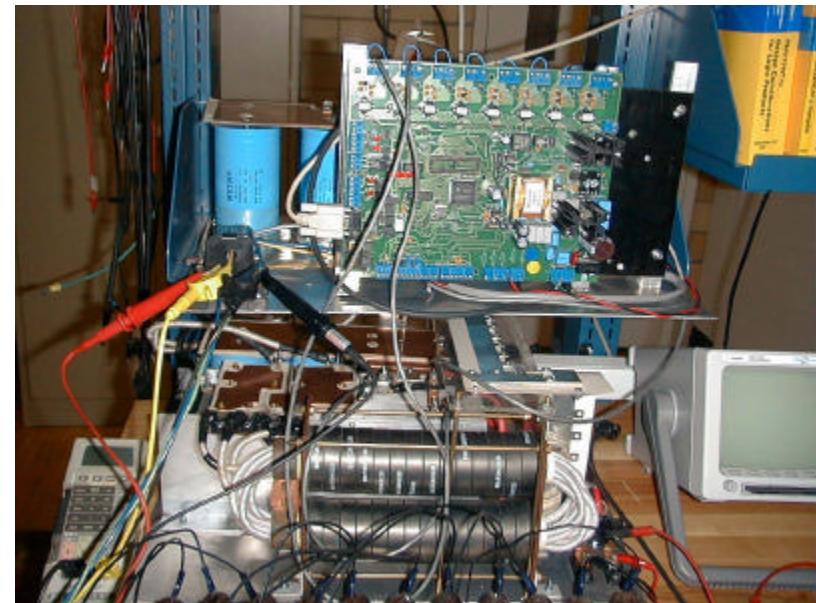
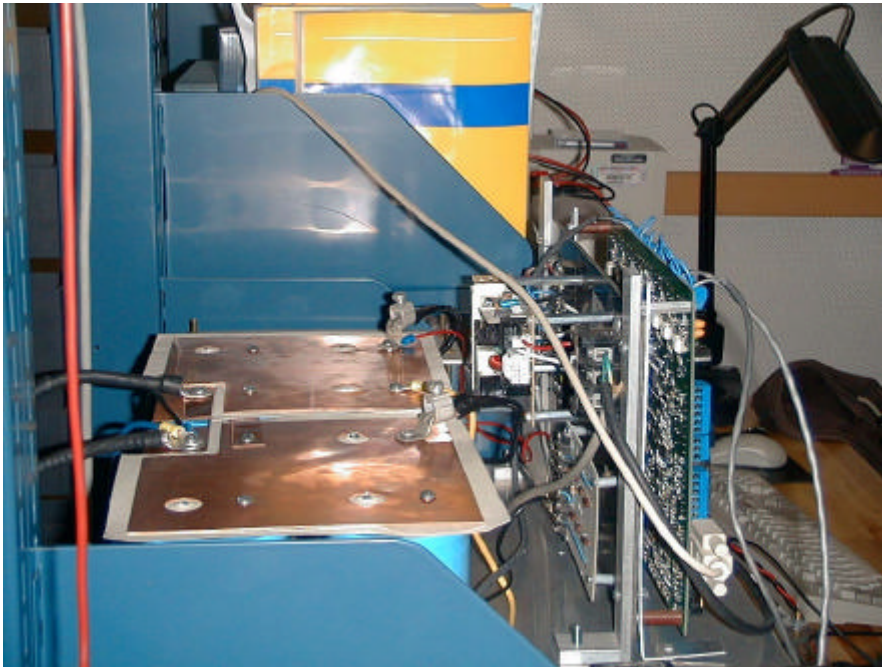
DR hardware emulator



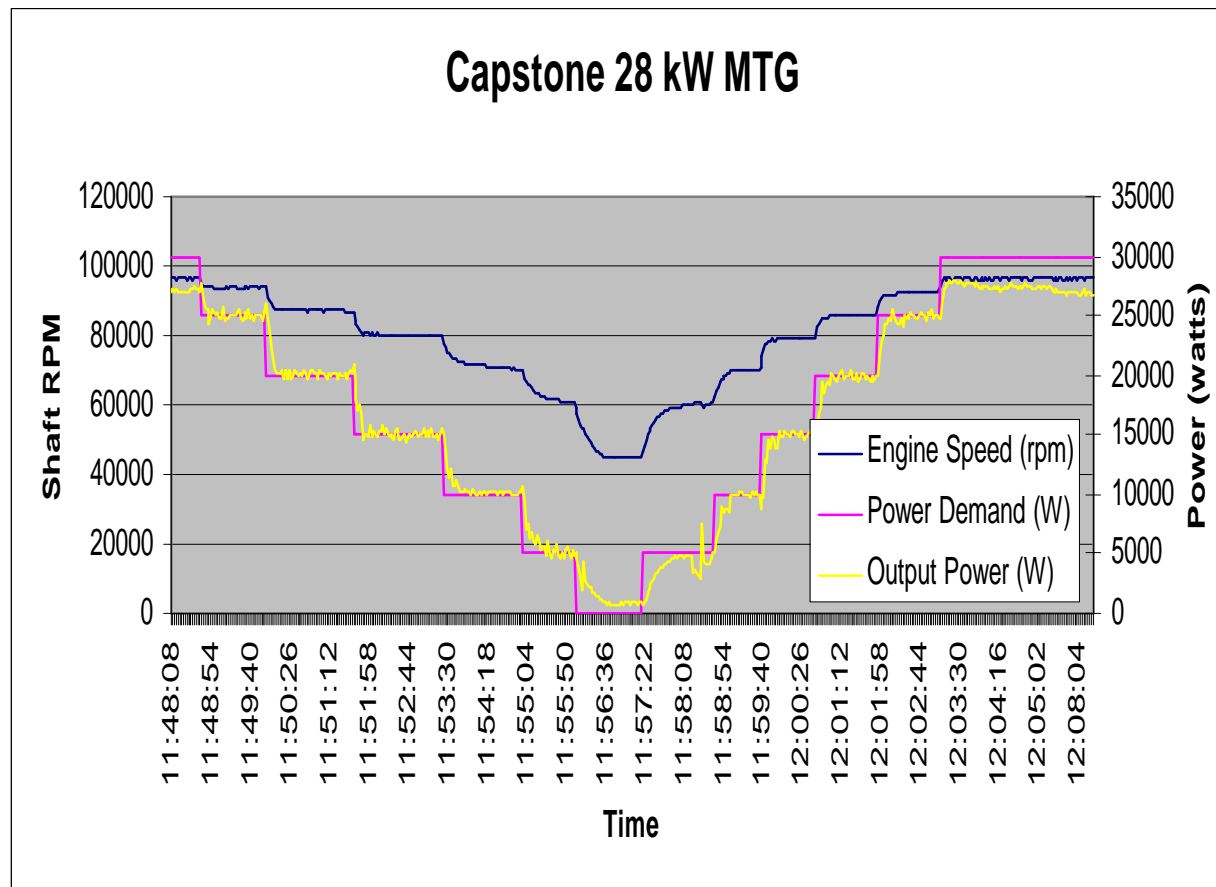
Emulator circuit



Emulator hardware

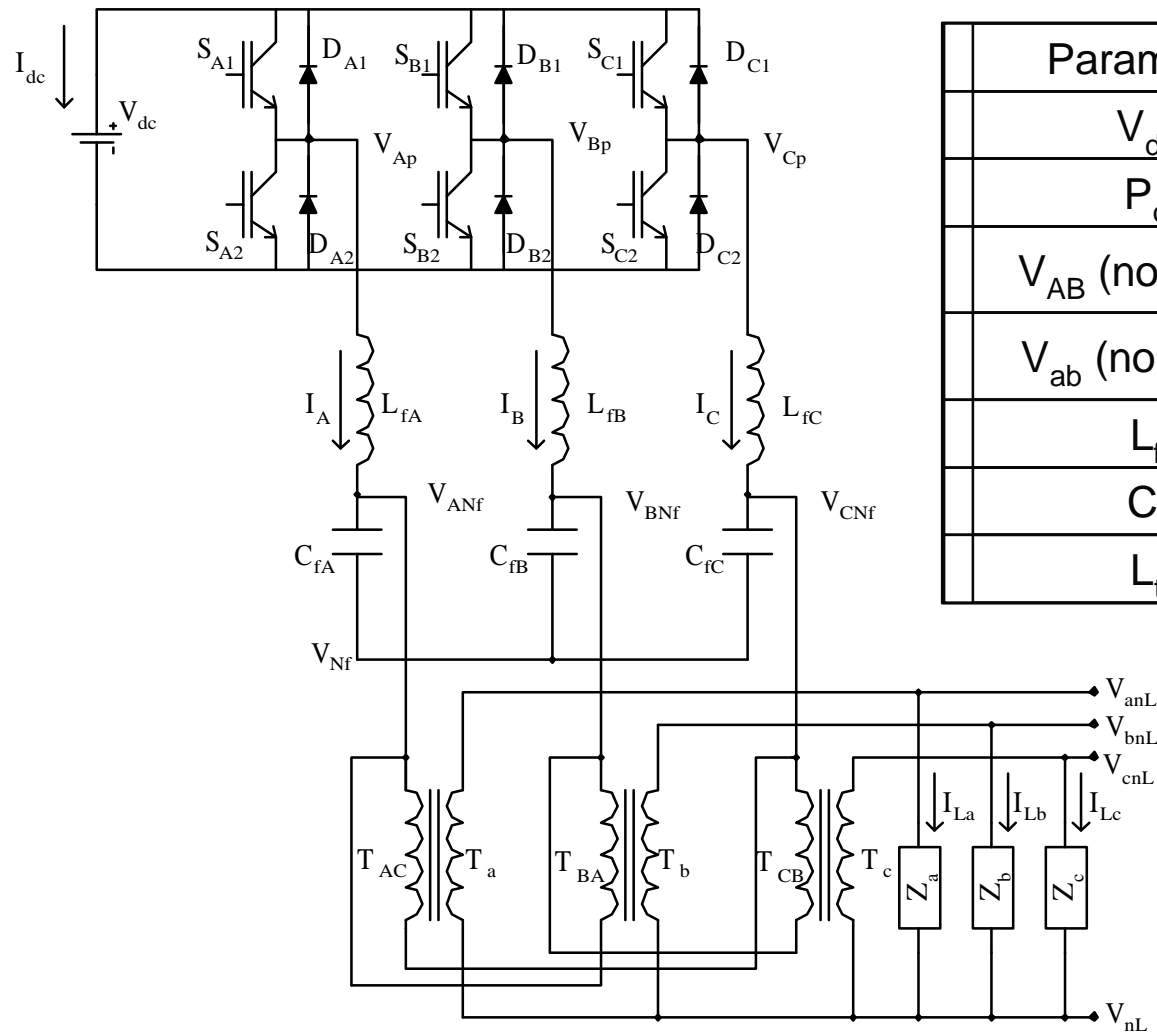


Field dynamics data to emulate



Response time for incremental loading

Three phase inverter



Parameter	Value
V_{dc}	750 V
P_o	15 kW
V_{AB} (nominal)	480 V
V_{ab} (nominal)	208 V
L_f	0.97 mH
C_f	180 μ F
L_t	2.1 mH

Inverter





Information Outreach



Discussions related to field applications of concepts

California Energy Commission

American Electric Power

Duke Energy

Northern Power Systems

Greystone Power Corporation

Solectria

IEEE PES Panels: summer 01, winter 01 & 02

UW extension short courses of DR systems

Conclusions

1. Successful simulation of control strategies
(needs to move to hardware)
 - Reactive Power-Voltage Droop Characteristics
 - Real Power-Frequency Droop Characteristics
 - Correct voltage sags deviations
 - Island and feed local critical loads upon large deviation
2. Constructed a prime mover emulator
3. Constructed hardware platform
4. Investigated the operation of an inverter based source on our hardware platform